

PS High Resolution Geochemistry at Well Site, A New Emerging Tool*

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Search and Discovery Article #42441 (2019)**

Posted September 23, 2019

*Adapted from poster presentation given at AAPG Hedberg Conference, The Evolution of Petroleum Systems Analysis: Changing of the Guard from Late Mature Experts to Peak Generating Staff, Houston, Texas, United States, March 4-6, 2019

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Abstract

It is apparent that the recent impressive improvements in analytical chemistry have already made it possible to transfer some geochemical lab activities to well site. This advance has come about partly due to the growing needs of environmental monitoring and additionally due to rapid developments in nanotechnologies. New portable and more robust devices, able to replace bulky and complex instruments previously restricted to the laboratory, have now been adopted in mud logging units at the wellsite. The trend is still ongoing and further analytical techniques are expected to be moved soon, opening up new opportunities to obtain additional high value data sets which match lab quality standards, but gather data in quasi-real time. There are many benefits deriving from moving geochemical analyses to well site: quick responses for optimization of well construction and facilitation of real time decision making, fresh sample availability for more accurate analyses, avoidance of complex procedures for exporting and shipping samples, less cost or what is even better, more data for the same budget. Petroleum system modelling requires the largest possible amount of experimental data to properly constrain the results of numerical simulations and well site geochemistry can supply highly detailed profiles of different analytical data, crucial for appropriate calibrations. A further benefit of geochemistry at the well site is an additional flexibility in sampling, based on analyses results. Cuttings samples are conventionally taken at regular intervals, defined in advance by the well program: sampling frequency is therefore often inflexible and is similar in both homogeneous and/or less important sequences of the well and in highly heterogeneous formations such as reservoir and source rocks. By using geochemistry at well site and evaluating the results in real time, it is possible to change and adapt sampling intervals, taking additional samples or different types of samples where heterogeneities are evident, or in key formation intervals. Thanks to lower cost and to the consequent possibility to obtain more samples and analyses, in addition to the flexibility in sampling frequency, a higher definition integrated picture of reservoirs and source rocks can be obtained. “Integrated” applies here to a stringent integration of fluid compositions and rock properties, to investigate and to correlate fluid and rock heterogeneities. The quantity and quality of data obtained through this approach can be seen to have a great impact on the models developed during Petroleum System Analysis studies. Among the discussed examples, the first one originates from the integration of XRD and XRF data, combined with TOC and Hydrogen Index; the combination generating a high-resolution chemostratigraphic mapping of different formations. Ratios between different chemical elements, created by specific paleo-environmental conditions limited in time, may be used to differentiate zones within homogeneous and uniform sedimentary sequences, this zonation often being well-correlated with source rock quality (Tribovillard et al., 2012). To better constrain basin

geometrical evolution through time, inter-well correlations may be identified, allowing for detailed reconstructions of sedimentation processes. Chemostratigraphy based on XRF and XRD can be fruitfully utilised in this role (Craigie, 2018). To detect the necessary elemental ratio anomalies, it is very often necessary to have a high frequency sampling strategy, only made possible by the wellsite approach. The second case history is based on the integration of fracture detection through Electromagnetic Flowmeters for mud delta flow (Fontenla Alvarez et al., 2015) with the description of oil quality through the on-site Thermal Extraction– Gas Chromatography analysis of cuttings (Turrisi et al., 2017). The study of fluids in an entire well profile shows how oil becomes generally heavier with depth, most likely due to incipient biodegradation in the lower section. Of further note in the shallow reservoir where fractures are detected, there is an evident bimodal distribution of the n-alkanes, suggesting a possible mixing of the original biodegraded oil with a second, undegraded fluid. This data can be used to identify the charging mechanisms of the reservoir: the most likely interpretation being that the primary filling of the reservoir is related to a first generation and migration event, followed by a slight biodegradation affecting the light fraction of the oil and completed by a further filling with a more mature (lighter) oil, migrating from below via fractures. The indication of multiple charging events has a strong impact on the model of the petroleum system, opening the door to the possibility of having more than one source rock active in the area, or to a complex burial history.

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High resolution geochemistry at well site, a new emerging tool

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INTRODUCTION

The recent impressive improvements in analytical chemistry, due on one side to the growing needs of environmental monitoring and on the other to fast developments in nanotechnologies, made possible to move part of geochemical lab activities to well site. New portable and more robust instruments, able to replace bulky and complex instruments used in the labs, have been adopted in mud logging units, to introduce geochemistry at well site. This trend is still ongoing and other analytical techniques will be moved soon, offering new opportunities to get in quasi-real time additional high value data, matching lab quality standards.

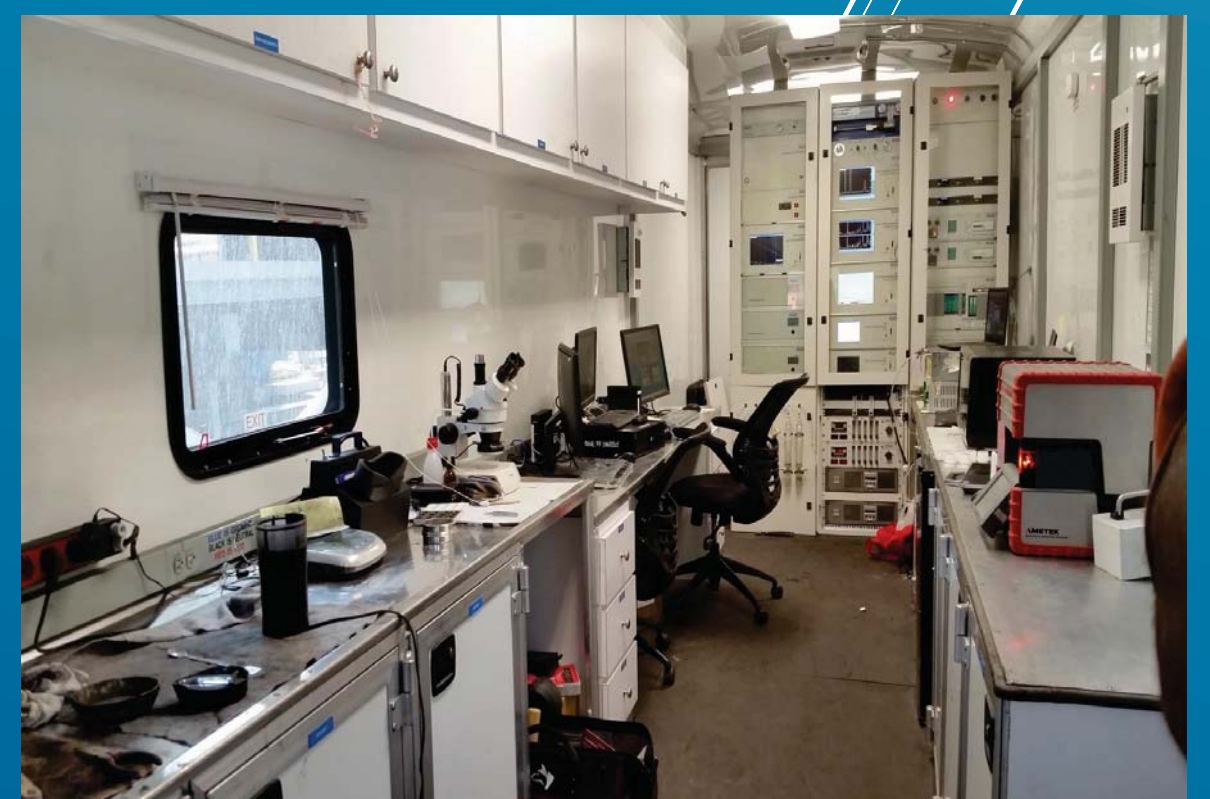
There are many benefits deriving from moving geochemical analyses to well site:

- **quick responses for optimization of well construction and of real time decisions,**
- **fresh samples availability for more accurate analyses,**
- **no need of complex procedures for exporting samples and shipping them,**
- **less costs or, even better, more data with the same budget,**
- **flexibility in sampling.**

Petroleum system modelling needs the largest possible amount of experimental data to properly constrain results of numerical simulations and well site geochemistry can supply very detailed profiles of different analytical data, crucial for appropriate calibrations.

One under evaluated benefit from geochemistry at well site is flexibility in sampling. Cutting samples are very often taken at regular intervals, defined in advance by well program: sampling frequency is sometimes similar in very homogeneous and less important sequences as well as in highly heterogeneous formations, such as reservoir and source rocks. By using geochemistry at well site and evaluating results in real time, sampling intervals can be adapted in the key formational intervals or where heterogeneities are evident.

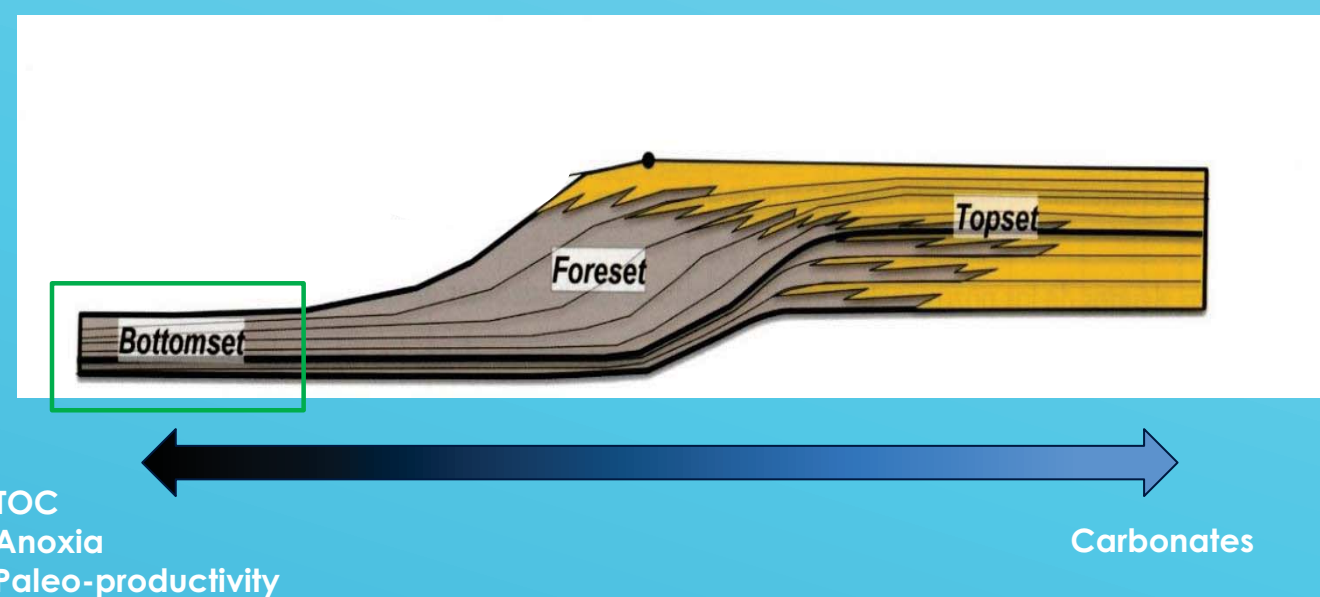
Thanks to lower cost and to the consequent possibility to get more samples and analyses, and to the flexibility in sampling, a high definition integrated picture of reservoirs and of source rocks, to be used as input to PSM exercises can be obtained. "Integrated" stands for a stringent integration of fluid compositions and rock properties, to investigate and to correlate fluid and rock heterogeneities.



Case History #1 – Well Site Source Rock Characterisation

Geological context:

- Complex stratigraphy of marine and continental succession, resulting from many relative sea-level changes at different scales
- Mixed siliciclastic-carbonate ramp (mid-distal), where TOC values range from 1 to 8%, and kerogen is mostly of type II/III.
- Both conventional and unconventional exploration.
- Variable kerogen maturity and complex charge mechanisms makes both light oil and gas interesting targets



Based on well-site acquisition:

- Portable XRD and XRF on cuttings
- Portable TOC and Pyrolysis
- C1-C5 mud logging

XRF, XRD and TOC data can give key information for reconstruction of source rock deposition.

Paleoenvironmental proxies

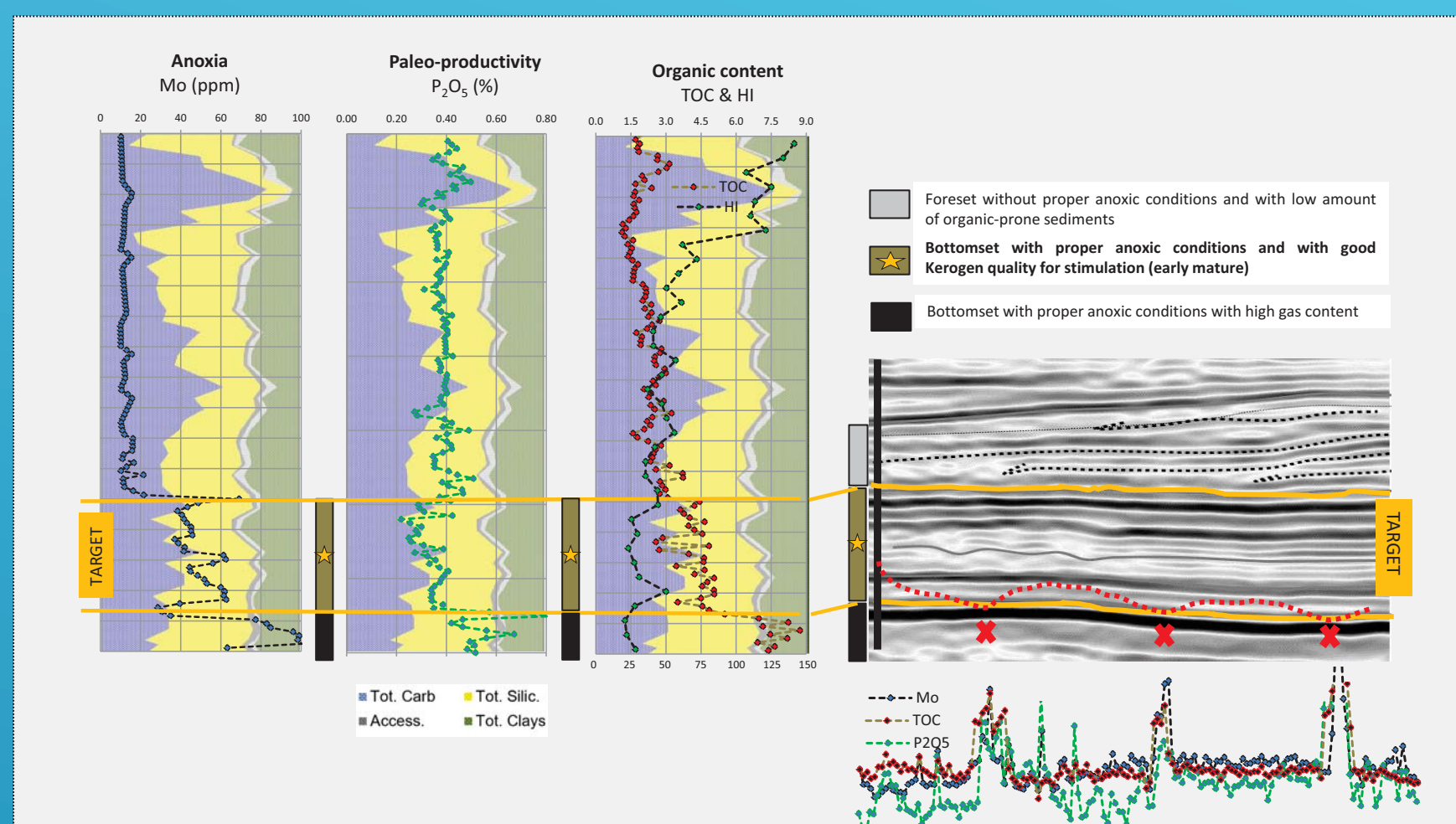
Mo concentration → Anoxia

P2O5 concentration → Productivity

Organic content proxies

TOC → Quantity of Organic Matter

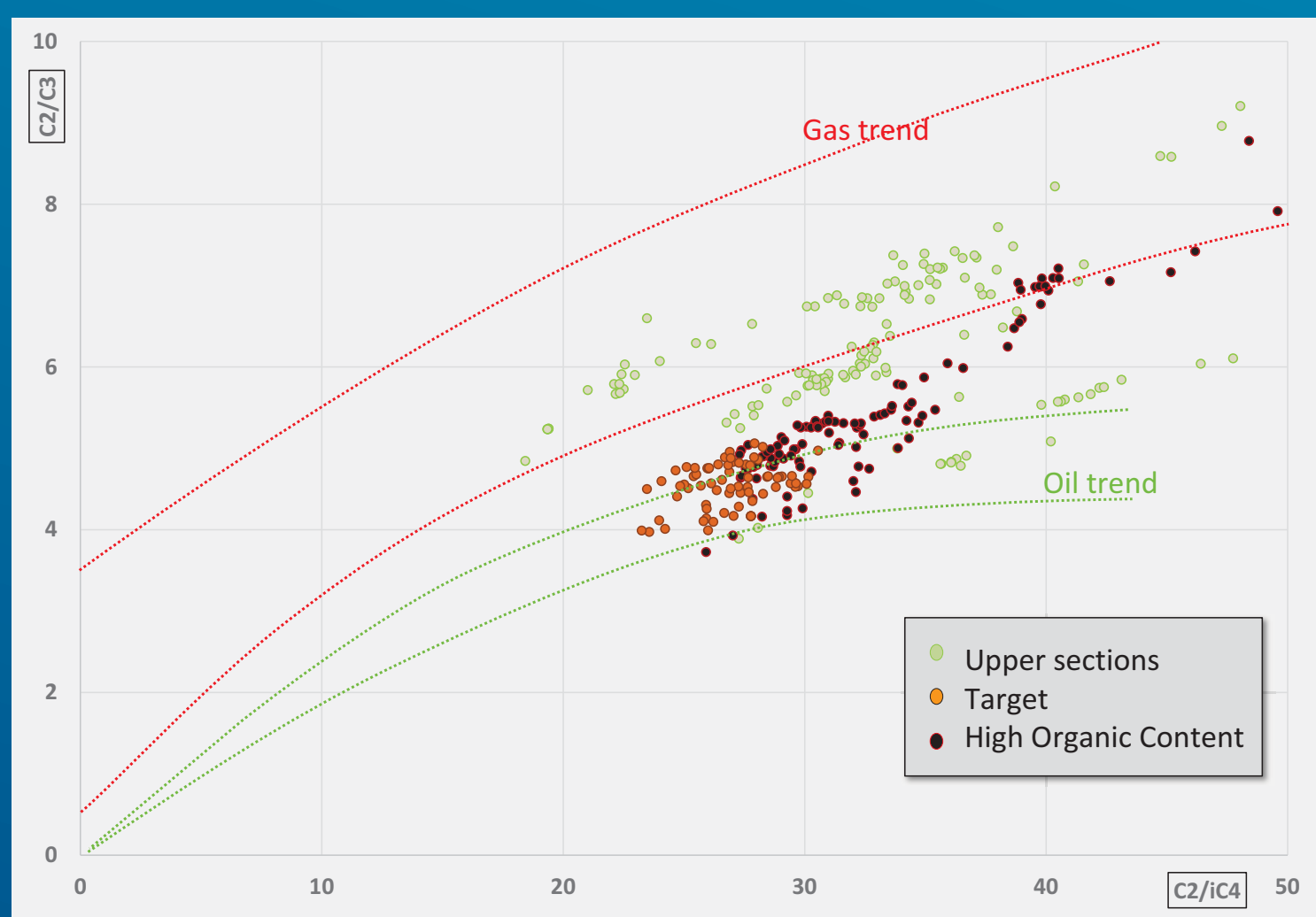
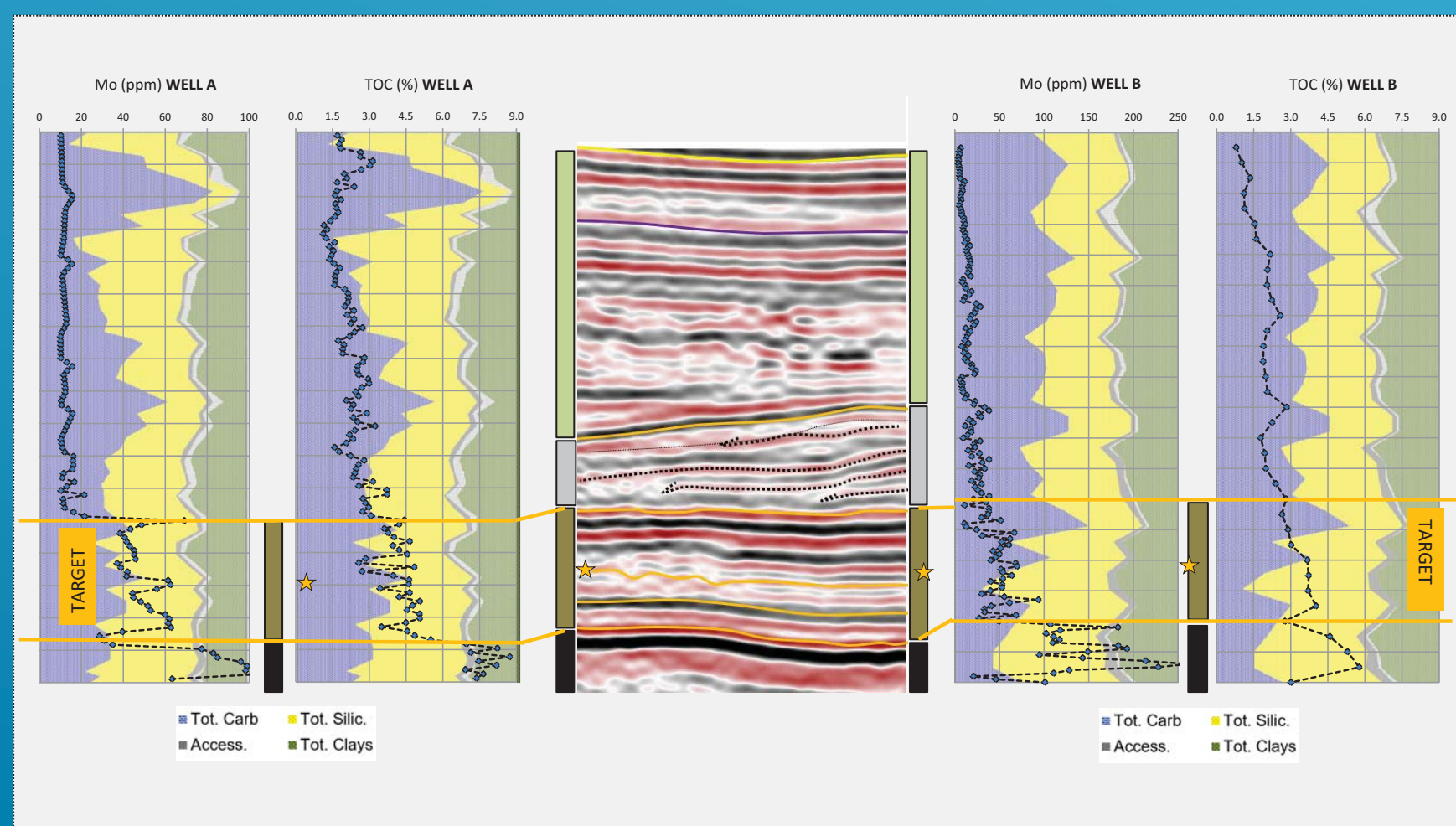
Hydrogen Index (HI) → Kerogen Quality



Well-well correlation

A better constrain of the basin geometrical evolution through time needs inter-wells correlations.

High resolution chemostratigraphy based on XRF and XRD can be fruitfully used at this aim. Concentrations and ratios between different chemical elements, due to specific paleo-environmental conditions limited in time, can differentiate homogeneous and uniform sedimentary sequences, allowing inter-well correlations using intra-formation horizons.



Fluid characterisation

Mud gas data from two wells indicates that:

- the target section is the most likely oil bearing interval;
- The shallow sections contains mostly gas, due to the poor quality of kerogen;
- the organic reach section at the bottom of the well can be both oil and gas bearing, probably depending on the local maturity and/or on gas charging from the deep.

Case History #2 – Multiple generation events

Based on well-site acquisition:

- Electromagnetic Flowmeters for mud delta flow
- Portable XRD and XRF on cuttings
- Portable GC-FID on cuttings

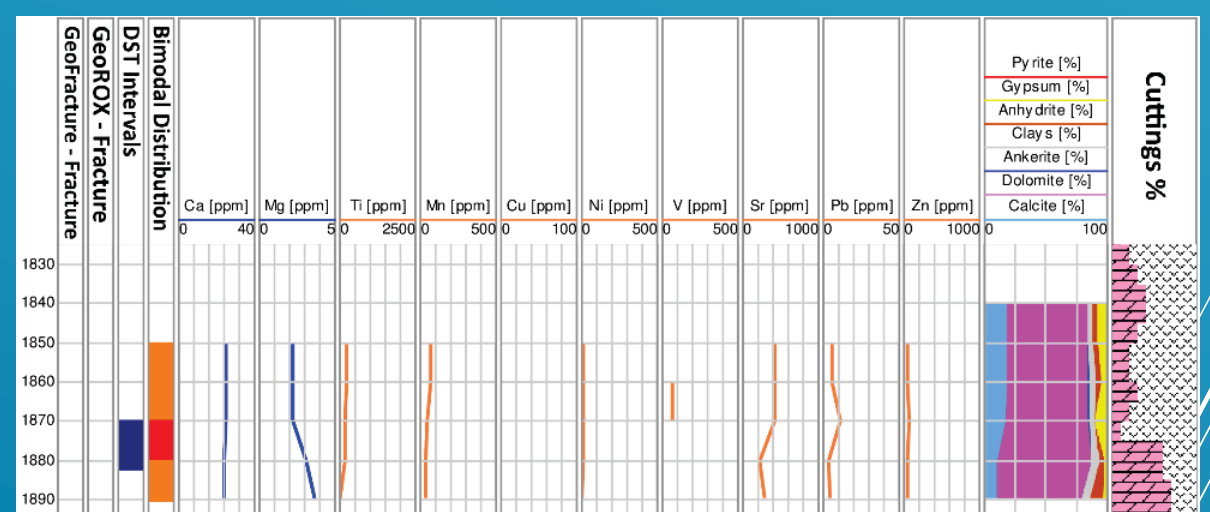
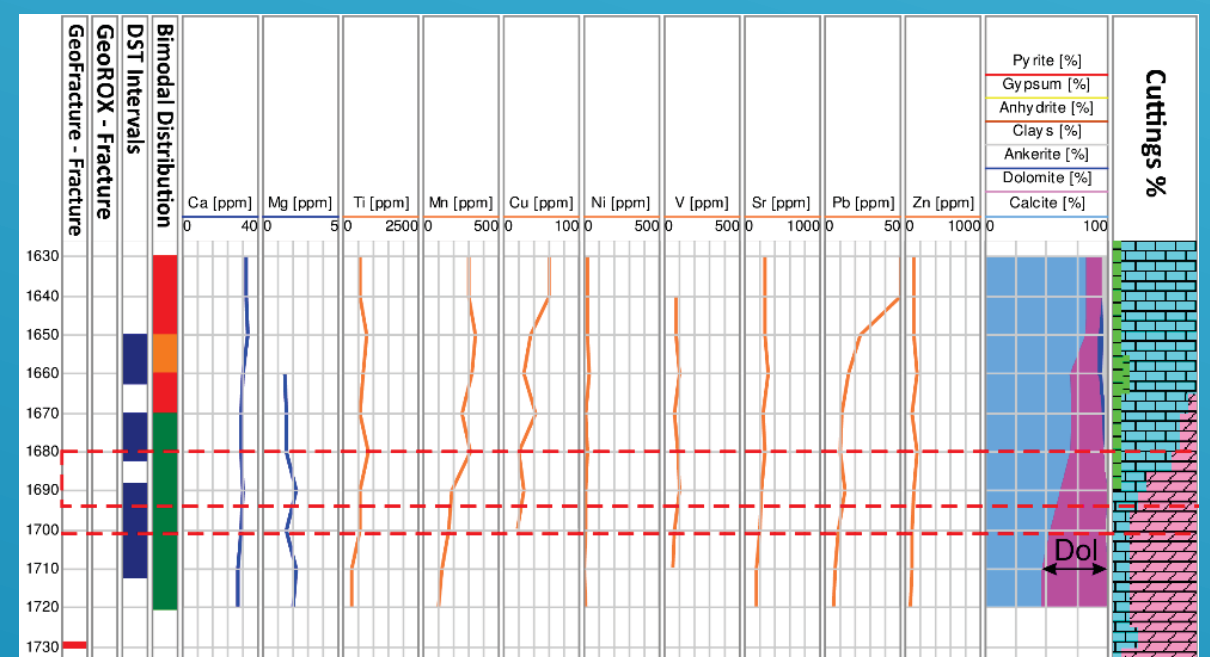
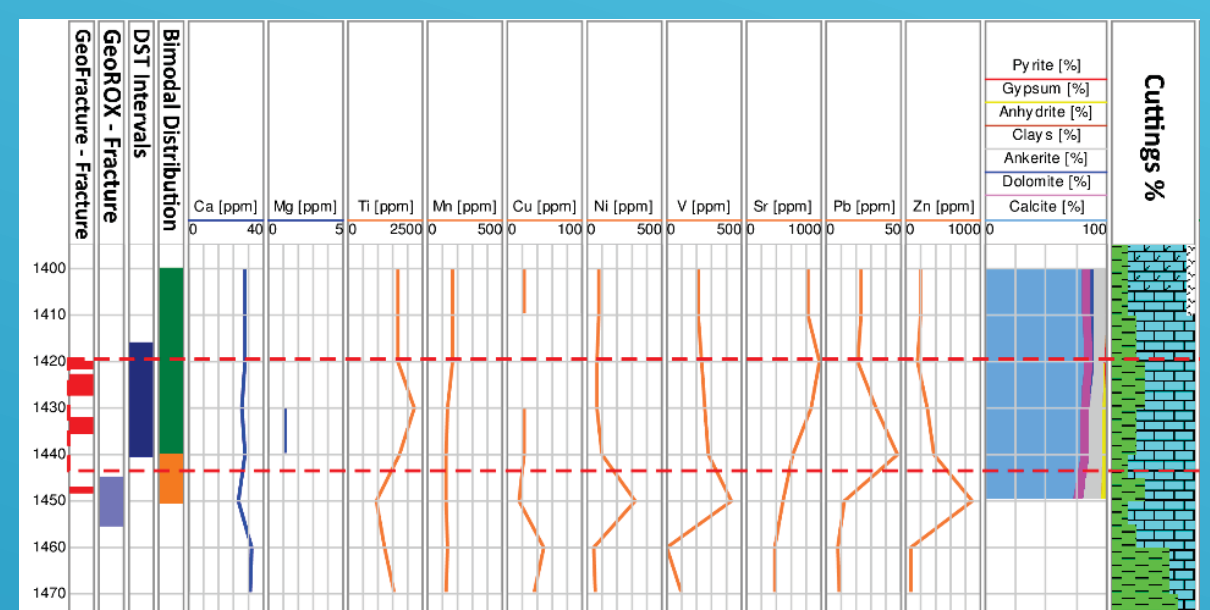
Oil becomes heavier with depth.

Incipient biodegradation in the bottom section: loss of the lighter n-alkanes and increasing UCM

Bimodal distribution in the shallow reservoir. A significant “hump” is still present

Fractures detected only in the shallow reservoir

- changes of the mud flow
- possible cement precipitation (Sr, Pb, Zn)

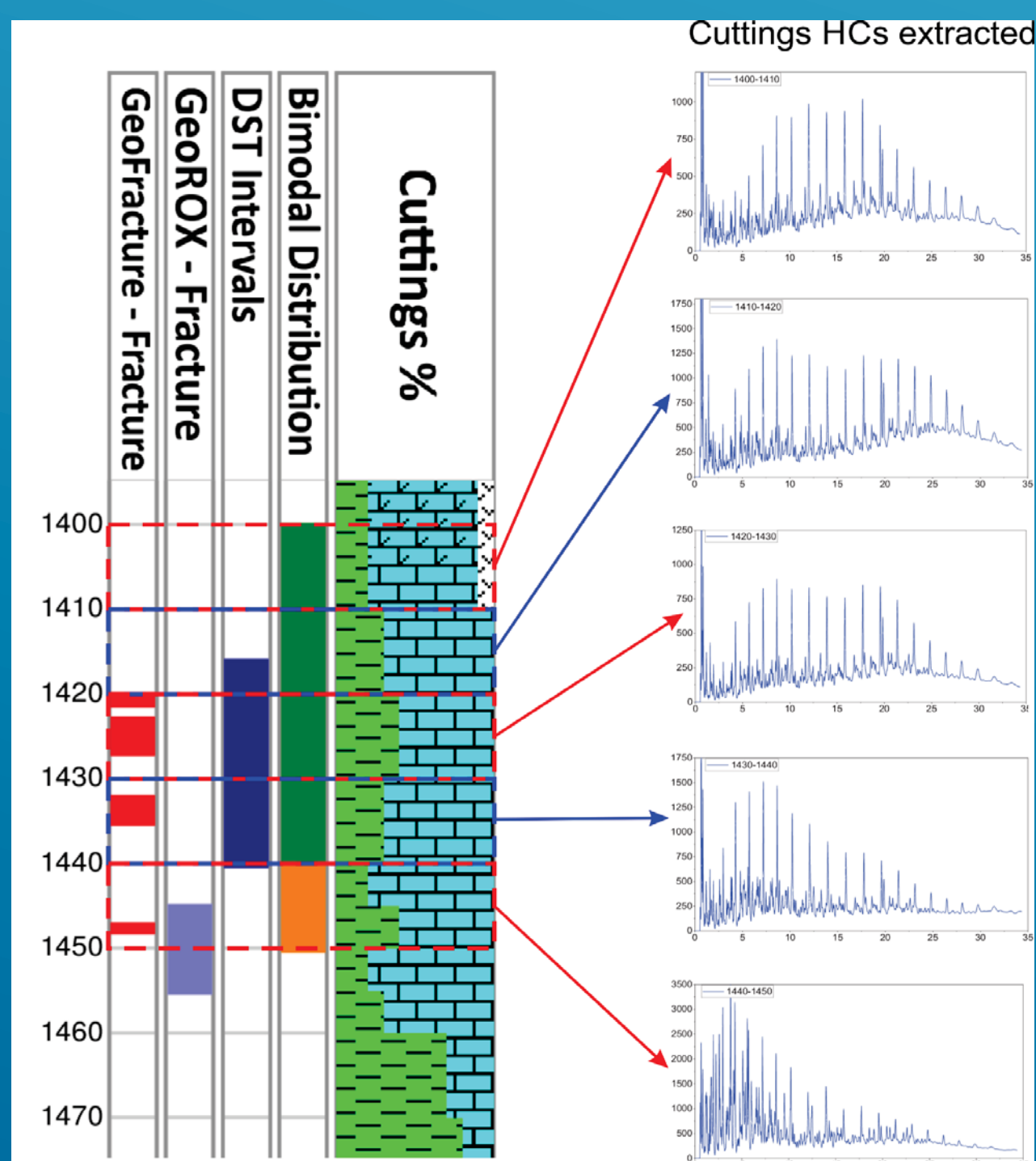


Interpretation:

- Filling of the reservoirs by a first generation and migration event
- Slight biodegradation affecting the light fraction of the oil
- New filling of a more mature (lighter) oil through fractures

Detailed picture of the fractured interval

highly heterogeneous oil quality
mix of biodegraded + lighter/non-degraded fluid



Final Remarks

- Labs activity can fruitfully and progressively move to wellsite.
- More data can be acquired at well site at lower costs, adding significant value.
- Data integration is crucial, adding huge value.
- New important progresses are still made possible by research activity.